FEBRUARY, 1926 BULLETIN 245

VIRGINIA POLYTECHNIC INSTITUTE

Virginia Agricultural Experiment Station

BLACKSBURG, VIRGINIA

A BEARING FAMEUSE TREE 138 YEARS OLD

Planted by the Hessian soldiers who were prisoners in the Revolutionary War, it has a girth of 92 inches and a diameter of 34 inches. This and fifteen other trees planted at the same time have survived and most of them are bearing regularly. This orchard is 3 miles north of Winchester, Va.

Apple Disease Studies in Northern Virginia

By F. J. SCHNEIDERHAN

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*In co-operation with the State Board of Agriculture. †State Crop Pest Commission.

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BY

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INTRODUCTION

The purpose of this bulletin is to present in a brief manner some results of the research with diseases of fruit carried on at the Winchester Field Laboratory. The work to be reported deals chiefly with the important fungous diseases of the apple, but some additional studies, especially those that treat of the climatic factors influencing the apple business, fungicides, spray injury and such records as have a direct bearing on apple production, particularly in northern Virginia, will be included.

The Winchester Field Laboratory is maintained by the Virginia Agricultural Experiment Station and the Virginia State Crop Pest Commission. The work deals chiefly with the control of diseases and insect pests of apples. It was begun in 1921 when the growers in Frederick County asked for assistance and advice in the control of the codling moth and aphis which were causing heavy losses. An entomologist was stationed at Winchester in that year by the Crop Pest Commission and has since been carrying on extensive investigations on the life history and control of codling moth, aphis, leaf roller and scale. Later the entomologist became a joint employee of the Crop Pest Commission and Experiment Station.

In 1921 certain fungous diseases, particularly scab, caused severe losses in apple production. In response to requests for help in the control of these diseases, the Virginia Agricultural Experiment Station stationed a plant pathologist at the laboratory in 1922 and he has been at work there since that time.

The initial work was carried on under unfavorable conditions for two years because of inadequate laboratory facilities. The laboratory was an old barrel shed without such conveniences as running water and electricity. Valuable instruments could not be kept there and very few of the growers knew where the laboratory was located.

Paper No. 67 from the Department of Plant Pathology. Edition of 12,000 copies.

In 1923 a suggestion was made to the Secretary of the Frederick County Fruit Growers Association to provide more suitable quarters. This suggestion met with immediate response in the form of a new laboratory building on a desirable site.* This building was amply equipped by the Virginia Agricultural Experiment Station and the Virginia State Crop Pest Commission to carry on the work under very favorable conditions. The Field Laboratory has become a center of research on apple diseases and insect pests and a clearing house for useful orchard information for the growers of the Upper Valley section. It is extensively patronized by the growers who call in person or use the telephone.

The apple disease which was causing the greatest losses in Virginia in 1922 was scab and the work thus far has centered largely around this disease. As will be shown subsequently, its control by spraying has been clearly worked out. The other diseases investigated are bitter rot, blotch, and cedar rust. The information accumulated in the experimental work was used to assist the Virginia Spray Service, through which the fruit growers are advised as to the time to apply and the materials to use in the different sprays. The Winchester Field Laboratory has been the source of much of the information upon which the recommendations of the Spray Service are formulated.

Besides the regular disease research, other problems are under investigation, such as testing of new fungicides, the factors entering into spray-burning of different types, orchard equipment in relation to acreage handled, the effects of frosts and other climatic factors on the apple crop and the causes that have resulted in the high percentage of cull apples.

As a result of the four years of work, data are now available which make possible a more economical and effective spray program than that formerly used. The effectiveness of the materials and the relative values of each spray are better known and it is no longer necessary to follow the scab control recommendations of other states where conditions are different from those in Virginia. In the experimental orchards, and in commercial orcharding as well, the practical application of our recommendations has been proven repeatedly. Scab and other diseases have been effectively controlled.

Since scab has been the disease of greatest importance in this State the results of our studies of this disease will be discussed first.

*Acknowledgment is here made to the Frederick County Fruit Growers Association for financing the laboratory building and to the Shenandoah Vinegar Company for furnishing the site for the building.

APPLE SCAB

The apple scab disease, as stated previously, had become of major importance at the time when our experimental work began. Growers were suffering severe losses and had lost confidence in the spray materials and spray schedule in use at that time. Although scab has been present in Virginia orchards for a number of years it had not been generally present in epidemic form until about 1919. In this year and in 1921 the losses in the Winchester section were especially severe.

Our first object in this study was to determine if satisfactory control of scab could be effected with standard spray materials applied on a schedule timed by the development of buds, blossoms and fruit. Also, to determine the importance in scab control of the different spray applications and the effect of variation in seasonal conditions. A study of the scab fungus and of its relations to weather was also made in order to interpret the results of the spraying work to the fullest extent.

Spraying experiments with these objects in mind were conducted throughout the four-year period in several commercial orchards in the vicinity of Winchester. A report of the work of the first two years has been published in Bulletin 236 of the Virginia Agricultural Experiment Station and the reader is referred to that bulletin for details of the life history of this disease and a more complete account. Only summaries of results will be given here.

Experiments in other States, particularly north of Virginia, have shown that apple scab is a cool-season, wet-weather disease and that a delayed dormant or pre-pink spray (applied between the time of opening of leaf buds and the pink stage of the blossoms) must be applied for adequate control. The pink spray is also valuable and together with the pre-pink is always applied in northern apple sections where severe scab injury is anticipated. Some doubt as to the importance of the pre-pink spray under Virginia conditions had arisen as a result of some preliminary experiments and this was one of the points given especial consideration in our investigations.

We have followed the Virginia spray calendar in our work, using the standard materials and the time of application recommended there. Winter strength of lime-sulfur, one part of the concentrate in eight parts of water, was used in the delayed dormant spray; summer strength of lime-sulfur, one part of the concentrate in forty parts of water, was used in the pink, calyx and 10-days sprays; and Bordeaux mixture, 3-4-50, for all the subsequent sprays which vary in number from two to three according to the seasonal needs. There had been little question in our minds as to the

efficacy of these materials for scab control and consequently no study was made of other spray materials.

A knowledge of the relative values of the different sprays in scab control is of importance to the grower who raises scabby varieties, as this knowledge enables him to pay particular attention to the important sprays. Data on this point were obtained through experimental work in commercial orchards. A series of plats were selected and in one of these all of the sprays of the program were applied, while in another no sprays were applied; in each of the remaining plats one separate spray was omitted so that the percentage of infection in such a plat, as compared with that obtained with the complete program, represented the effect of omitting a particular spray. The plat with all sprays omitted served as an index of the intensity of scab infection and was particularly valuable for comparisons between different years. Regular orchard equipment was used in the work and particular care was exercised to mix the spray materials properly and to apply them at the times recommended by the Spray Service.

The four years, 1922 to 1925 inclusive, have represented the extremes of weather conditions apt to be encountered at Winchester. In 1922 the weather was wet, especially in the early season when most of the scab infection takes place. In 1924 occurred the wettest spring in the history of the U. S. Weather Bureau records for Winchester. Contrasted to these wet years when severe scab epidemics occurred, the years 1923 and 1925 were unusually dry, particularly 1925 when the total rainfall for the growing season, from April to October inclusive, was nearly six inches below the average for those months in the ten-year period, 1916 to 1925, inclusive. In these dry years scab infection and development was largely inhibited and the disease was of minor importance. A comparison of the severity of scab on fully sprayed and on unsprayed fruit during the four seasons may be seen in Table 1 which shows the percentages of scab-free fruit in plats receiving the full program of sprays and in plats that were not sprayed. It will be seen that in 1923 and 1925 high percentages of scab-free apples occurred even though no sprays were applied, while in the other years the omission of all sprays resulted in very low percentages of scab-free fruit. The control obtained with the full program is consistently high throughout the four years.

Table 1.—Percentages of scab-free apples in plats receiving the full program of sprays compared to those which received no spraying. Winchester, Va.

Year	Variety	Percentage of scab-free fruits	
		Full program	No spraying
1922	Winesap	93	3
	Rome	82	2
	Stayman	95	24
1923	Winesap	100	92
	Rome	100	96
	Stayman	100	97
1924	Winesap	91	22
	Stayman	95	32
	Stayman	90	4
1925	Stayman	98	93

It has been possible from these experimental plats to calculate the value in scab control of each spray in the program and these values have been quite consistent throughout the four years. Only a summary of the conclusions will be presented here.

The delayed dormant spray is of minor importance as a scab spray in Virginia. It is difficult to assign to it any value for scab control except a slight one in occasional years. It is primarily an aphis and scale spray. The pink and calyx sprays are approximately equal in value for scab control and together they account for about 80 per cent of the total control. They are by far the most important scab sprays. The 10-days spray is also an important scab spray, valued at 10 per cent, while the 5-weeks spray accounts for 5 per cent of the seasonal control. All other sprays, including the delayed dormant spray, make up the control percentage not accounted for by the sprays previously mentioned. This amounts to 5 per cent.

Studies of the ejection of ascospores from over-wintered leaves have furnished data which clearly explain the major facts of scab control in Virginia. We knew previously that rainfall was the immediate cause of winter spore ejection but now we are able to state why the time and the amounts of these rains in the early spring determine, to a large extent, the amount of scab infection in any particular year. The rains in May have been found to be the most important factor in scab epidemics in Virginia.

The ejection of winter spores is important because these spores cause the first scab infections in the spring.

In 1922 there were sixteen spore ejections, covering a period of fifty-six days, and the scab infection on unsprayed fruits of Rome, Stayman and Winesap averaged 95.5 per cent. In 1923 there were thirteen ejections covering a period of ninety-four days but the average infection on un-

sprayed trees was only 2.2 per cent. In this year the individual ejections were very light and drawn out over a period of drought in which infection was inhibited. In 1924 there were fourteen ejections of winter spores covering a period of sixty-one days with an average infection of 90 per cent on unsprayed trees of Stayman and Winesap. This was the wettest year of the four included in this study. In 1925 we recorded thirteen ejections covering a period of only thirty-one days, followed by an infection of 6.5 per cent on unsprayed fruits of Stayman. The variability in the number of ejections and in the length of the periods during which they occur is evident. There is a close connection between scab spray values and the time of spore ejections.

Table 2 explains the correlation between the dates of spray application and of winter spore ejection in northern Virginia for the years 1922 to 1925 inclusive. These data indicate why the pink and calyx sprays are the most important scab sprays and why the delayed dormant is not of major importance.

Table 2.—The correlation between the dates of spray application and ascospore ejections for the four years 1922-1925 inclusive at Winchester, Va.

	1922	1923	1924	1925	Total Number	Per cent
DelayedDorm.	Mch. 30	Apr. 1	Apr. 8	Mch. 25		
Spore Ejections			Apr. 18 Apr. 20 Apr. 30	Apr. 10 Apr. 14	5	8.7
Pink	Apr. 13	Apr. 23	May 2	Apr. 14		
Spore Ejections	Apr. 18 Apr. 19 Apr. 20 Apr. 21 May 3 May 4 May 5	Apr. 28	May 7 May 8 May 10 May 11	Apr. 17 Apr. 23 Apr. 25 Apr. 26 Apr. 28	17	29.3
Calyx	May 5	May 6	May 17	Apr. 28		
Spore Ejections	May 10 May 11 May 14 May 17 May 18	May 10 May 11 May 15 May 20	May 20 May 27 May 29 June 1	Apr. 29 Apr. 30 May 4 May 5	17	29.3
10-days	May 19	May 23	June 3	May 18		
Spore Ejections	May 26 June 3 June 4	June 3 June 11 June 13	June 8 June 13 June 18	May 22 May 29	11	18.9
5-weeks	June 10	June 15	June 21	June 4		
Spore Ejections	June 11	June 23 June 28 July 6			4	6.9
10-weeks	July 13	July 6	July 5	June 20		
Spore Ejections		July 22 July 30		June 24 June 27	4	6.9
Total	16	13	14	15	58	100.0

Table 2 shows the dates of spray applications and of spore ejections, the latter being grouped as they occurred in the intervals between sprays. In 1922 and 1923, for example, there were no spore ejections in the intervals between delayed dormant and pink and since the pink intercepted the first ejections of spores the delayed dormant was unnecessary in scab control. In 1924 and 1925, however, there were 5 spore ejections in this interval and these were subject to control by the delayed dormant. But since the spray plats show that no appreciable increase in scab infection followed the omission of the delayed dormant in these years the conclusion is justified that this spray is of little value in scab control in the Winchester section.

The importance of the pink, calyx and 10-days sprays is shown in Table 2. Of a total of 58 spore ejections in the four years, the pink and calyx together intercepted 58.6 per cent, the 10-days 18.9 per cent, and the delayed dormant, 5-weeks and 10-weeks together 22.5 per cent. It has been evident throughout the work that the very early season and the late season ejections of spores seldom result in infection, apparently because of unfavorable temperatures, and the importance of the delayed dormant, 5-weeks and 10-weeks sprays is less than the table would seem to indicate.

In 1922 and 1924, the years of scab epidemics, most of the spore ejections occurred in the month of May, approximately 56 and 50 per cent of the total ejections of the respective years. In 1923 and 1925, years of slight scab infection, only 31 per cent of the spore ejections occurred in May. The ejection of spores is determined by rainfall and it is apparent that the rainfall of the month of May determines the severity of scab infection to a greater degree than that of any other month. In the years of severe scab, 1922 and 1924, the May rainfall was 3.63 and 10.75 inches, while that of the years of slight scab, 1923 and 1925, it was only 1.12 and 2.47. It is the rainfall, and the spore ejections that accompany it, of the blooming period especially, that determines the severity of scab infection for the season.

Does scab continue to infect fruit through the summer months? Late season infection has caused considerable losses in this State in certain years. In 1924 a study of the cycles of scab infection was carried through the spring, summer and autumn. It was found in this year that there were four rather distinct periods of infection, the first one coming to a peak on May 30, the second on June 19, the third on July 1 and a less distinct cycle appearing about October 1. The infection noted on October 1 was of the "pinhead" type which caused considerable damage in many orchards. The same study was made in 1925 but in this year a very slight initial infection was noted about May 10, and due to the abnormally low rainfall following, there was practically no secondary infection. The disease is spread during the summer by the summer spores which appear in the lesions on the fruit about two weeks after infection. These summer spores follow after infec-

tion caused both by winter spores and summer spores. They remain viable for months, which explains why late season infection may occur.

There is considerable variation in resistance of apple varieties to infection by scab but in planning the spray program it is unsafe to rely too much on the resistance of varieties. In years of severe scab the most resistant varieties may become infected. In certain orchards in 1922, York was infected to the extent of 60 per cent, although under average conditions this variety develops very little scab as compared to Winesap and Stayman. Of the common varieties grown in Virginia the following may be listed as susceptible: Winesap, Rome, Virginia Beauty, Lowry, Black Twig, Ben Davis, Gano, Delicious, Stayman, King David and Early Harvest. The less susceptible varieties are: Jonathan, Duchess, Transparent, York, and Grimes.

Summary of Scab Investigations

Thorough and timely spraying for scab should produce ninety, or more, per cent of scab-free fruit.

Weather has a direct bearing on the severity of scab infection. The most important factor of the weather is the number of rains in May and the amount of rainfall.

The relative scab control values of the different spray applications have been determined. The pink and calyx sprays are the most important and account for approximately 80 per cent of the total control valu^. The 10-days spray is valued at 10 per cent and all the other sprays at 10 per cent.

Control values of scab sprays are correlated with winter spore ejection. The pink and calyx sprays are most valuable because approximately 60 per cent of all spore ejections are intercepted or nullified by these sprays.

The materials and time for spraying recommended by the Spray Service have been found to be practicable in successful scab control.

The scab disease may in certain years continue to develop throughout the growing season. Four cycles of infection were recorded in 1924. Only one cycle of infection was noted in 1925.

In years of severe scab infection the so-called scab resistant varieties have become severely infected.

For the Virginia apple grower the most important practice for effective scab control is the thorough and timely application of the pink, the calyx and the 10-days sprays.

CEDAR RUST

In spite of the organized effort to control cedar rust in Virginia during the past 14 years through eradication of red cedars, there still remain large

areas of uncut cedar trees which are limiting factors to orchards of rust-susceptible varieties planted near them.

From the beginning of the cedar eradication campaigns until the present time the question of how far cedar trees should be removed from orchards to prevent serious loss, has been paramount. The Virginia cedar rust law at first assumed that beyond a one-mile zone was a safe distance but in the amended law a two-mile distance is considered safe. The present study of this disease was begun in the spring of 1925 to obtain exact data as to the relation which exists between infection of apples and distance from uncut cedar areas.

It is a long established fact that cedar rust on apples is the result of infection by spores produced by the galls on cedar trees commonly known as cedar apples because of their bright orange color during rains and immediately afterward. As in our work with scab, a record of spore ejections from the cedar apples was kept. For this purpose a small heavily infected cedar tree was transplanted to the laboratory grounds and all of the spore ejections in 1925 were recorded from this tree. These records were amplified by observing other cedar trees in uncut areas.

The spores which carry infection to apple trees are produced on the cedar galls following rainfall in the spring. The first spores in 1925 were produced on April 2 and during the season there were twenty-one separate ejections covering a period of 82 days between April 2 and June 23. The first rust spots appeared on apple leaves on May 11. which is comparatively early. The damage caused by rust in 1925 was slight as compared to other years. The spore ejection record partly explains this. The heaviest spore production occurred before most of the leaves had developed. If these early ejections had occurred later when the trees were in full foliage, it is quite probable that the infection would have been very severe. Furthermore, the growing season of 1925 was one of the driest on record, the total seasonal rainfall for the growing months, April to October inclusive, being nearly six inches below the average for these months during the past ten years. Dry seasons are unfavorable for cedar rust as well as other fungous diseases.

To determine the relation between infection of apple leaves and distance from cedars, three representative districts were selected: the first was at Mt. Jackson, the second at Clearbrook, eight miles north of Winchester, and the third in Clarke County, near Berryville, and at the point where the Boyce Road crosses the Opequon Creek.

On June 11, which was the date of maximum leaf infection, we examined the leaves of York trees in the Turkey Knob, the Cather, and the Whistler Orchards which lie nearly in a direct line from the cedars on the Mt. Airy Farm across the Valley Pike. Our observations were made

at four stations approximately 3, 2½, 2, and 1½ miles from the cedars. Stations 1 and 2 were in the Turkey Knob, station 3 in the Cather Orchard and the fourth station, nearest the cedars, was in the Whistler orchard.

Data for the Clearbrook section where the cedars are at Brucetown and the orchards extend three miles to a high ridge west of the cedars were taken two weeks later. In this locality four stations at distances of 3 miles, 2.2 miles, 1½ miles, and 200 feet from cedars were selected. There were elevated, wooded ridges between stations 1 and 2 and between stations 2 and 3 and the effect of these natural barriers on the interception of spores carried from the cedars will be shown. Along the Opequon Creek which runs between Clarke and Frederick Counties there are some of the largest cedars in northern Virginia and a station for observation was established about 75 yards from some of these large cedars. The fourth station was in

Table 3.—The relation of percentage and intensity of infection by cedar rust to distance from cedar tree areas at Opequon Creek, Mt. Jackson, Clearbrook, and Berryville sections, Virginia, 1925.

Opequon Creek Section

Cedar Trees	Station (75 yards)
XX	O
	Infection 91%
	Intensity 30 spots

Byrd Orchard, Berryville, Va.

Cedar Trees	Station (4 miles)
XX	O
	Infection 18%
	Intensity 2.2 spots

Mt. Jackson Section

Cedar Trees	Station 1 (1½ miles)	Station 2 (2 miles)	Station 3 (2½ miles)	Station 4 (3 miles)
XX	O	O	O	O
	Infection 77%	Infection 63%	Infection 57%	Infection 20%
	Intensity 11.5 spots	Intensity 8 spots	Intensity 4.3 spots	Intensity .32 spots

Clearbrook Section

Cedar Trees	Station 1 (200 ft.)	Station 2 (1½ miles)	Station 3 (2.2 miles)	Station 4 (3 miles)
XX	O	O	O	O
	Infection 85%	Infection 48%	Infection 17%	Infection 63%
	Intensity 11.4 spots	Intensity 2.6 spots	Intensity 1.4 spots	Intensity 2.6 spots

the Berryville orchard of Governor H. F. Byrd, four miles from the nearest cedars.

The data are shown in a semi-diagramatic form in Table 3, which gives the distance of the observation stations from the cedars, the percentages of leaves infected and the intensity of infection based on the average number of rust spots per leaf. The last figure is an average of all leaves, both the infected and uninfected.

It is plainly apparent that a direct relation exists in the Mt. Jackson section between infection percentages and intensity, and distance from cedars. Infection increases in direct ratio to the nearness of the cedars. We should expect this to be true wherever there are no natural barriers as in this particular instance at Mt. Jackson. The cedars are visible from all four stations.

The Clearbrook data at first glance would appear to be inconsistent with that for the Mt. Jackson section because the percentage and intensity of infection at the three-mile station was greater than at the two stations nearer to the cedars. This seeming discrepancy is explained by the presence of elevated, woody ridges on the windward side of stations 3 and 2 in relation to the cedars. These ridges prevented the normal dissemination of the spores by the wind. The three-mile station is on the highest point in the terrain and in full view of the cedars at Brucetown. This station was located in the orchard of L. O. Dick and the side farthest from the cedars is bordered by woods which probably acted as the final interception of the spores and caused a relatively greater infection there than at points nearer the cedars.

In the Byrd Orchard at Berryville, four miles from cedars, the rust infection was a negligible factor, there being an average of only 2.2 spots per leaf in this orchard.

The observations at the Opequon Creek were made in a small home orchard lying in the creek flat about 75 feet below the cedars and only about 75 yards away, an ideal setting for maximum infection. The heaviest rust infection observed in 1925 occurred here, there being an average of 30 spots per leaf. The leaves of these trees dropped early in the season and the fruit never developed beyond half of normal size.

There is another important consideration in cedar rust infection, namely, the number of spots per leaf which constitutes injurious infection. The West Virginia Experiment Station has investigated this phase of the problem. In Bulletin 39 of that station we find that 75.8 per cent of uninfected leaves remained on trees on November 1; that on the same date 55 per cent of leaves having one to four spots persisted; that only 26 per cent of leaves having five to nine spots remained and that 17 per cent

having ten to fourteen spots and 2.9 per cent having fifteen or more spots remained on the trees on November 1. From these data we infer that the maximum number of rust spots per leaf consistent with safety is about five and on this basis we conclude that in Virginia, in 1925, the danger zone would extend to approximately two miles from the edge of the uncut cedar tree areas.

There are still some growers and laymen who believe that cedar rust infection on apple trees is inherent in the apple tree, that it becomes infected and develops rust spots on leaves and fruits because of some unknown method of development inside of the tissues of the tree much like a skin eruption results from bad blood in an animal.

To demonstrate the fallacy of this view to the satisfaction of the doubtful ones we used the cedar tree and two small York trees planted three feet from it in the laboratory grounds in an experiment. Before any spore ejections occurred in the early spring, in fact before the leaves developed from the leaf buds on the apple trees, we prepared a muslin bag of the finest material available and covered one of the small York trees with it. The other tree was not covered. The leaves of the covered tree grew to normal size within the bag which permitted sufficient sunlight to penetrate. The uncovered tree developed an extremely heavy rust infection, resulting in the premature dropping of many of the leaves late in June. When the bag was removed from the other tree on July 19 not one rust spot could be found on any of the leaves. The muslin bag had effectually prevented the spores from the cedar tree from reaching the apple leaves and causing infection. This simple demonstration was observed by many growers who visited the laboratory. It is clear to any reasoning person that if cedar rust were inherent in an apple tree, the covered tree would also have been infected, since it grew normally. This same demonstration will be carried on in succeeding years so that any apple grower in Virginia who visits the laboratory may see it after the middle of July. Figures 1 and 2 show the trees used in this demonstration.

There prevails in Virginia an erroneous belief about the nature of rust infection over a period of years. We hear such remarks as "This is the off year," or "We are due for rust infection because last year was the 'off' year." The idea seems to prevail that cedar rust runs in definite cycles of infection and that by the very nature of the disease there are "off" years and following these are infection years. There is no scientific basis for this belief and its genesis no doubt lies in the fact that two years are required to complete the cycle of infection from apple to cedar and vice versa. As a matter of fact there is an exchange of infection between cedars and apples and vice versa, every year. In years of drought as in

1923 and 1925 there is a measurable diminution of infection, but the lack of rain which prevents spore production and infection explains this. The heavy infections in the three consecutive years of 1920, 1921 and 1922 effectively refute the ''off year'' theory. Climatic conditions being similar, the amount of infection at a certain distance from cedar trees will be very nearly the same from year to year.

The only permanent hope of removing the cedar rust hazard is to remove the cedar tree. The logic of this statement is simple, because the spores from cedar galls can only infect apple trees and the spores from the leaves of infected apple trees can only infect cedars. That spraying does not control the disease effectively has been shown in our scab experiments where during four years there has been no appreciable difference in the degree of rust infection between trees that received the full program of sprays and those that received none.

Figure 1.—Cedar tree in relation to a covered and uncovered York apple tree. Spore ejection records were obtained from observations on this cedar tree.

Figure 2.—The trees shown in figure 1 after removing the muslin bag on July 19. Defoliation and severe infection occurred on the uncovered tree while the covered tree did not have one leaf infected by cedar rust.

APPLE BLOTCH

This disease is of minor importance in Virginia as compared to scab and cedar rust except in occasional severely infested orchards. Many growers confuse it with scab, although the two diseases are easily distinguishable.

In the Winchester section there are several orchards which are very severely infested with blotch and practically all of the apples of susceptible varieties have been culls in recent years. Responding to the request for assistance, we undertook in 1925 a study of the disease in a severely infested orchard of Greenings. No investigational work has been done previously on the control of this disease in Virginia and the blotch spray program was based on the recommendations of other stations, particularly of Arkansas, Illinois, and Ohio.

It has been found in other States that blotch is effectively controlled with three or four applications of Bordeaux mixture at two-week intervals, beginning with the 10-days spray.

Five spray plats were selected in the orchard of Greenings and the plats were arranged, as in the scab work, to test the value of each applica-

tion in comparison with a full program of sprays, which for the blotch work alone, consisted of three applications. The 10-days spray was applied on May 15 and was of summer-strength lime-sulfur. It is generally known that lime-sulfur is less effective in blotch control than Bordeaux mixture, but we used it because it is less likely to cause russet of fruit. The 5-weeks spray was applied on June 2 and the 8-weeks on June 27; 3-5-50 Bordeaux being used for both applications. Approximately 20,000 apples were examined in obtaining the data which are shown in Table 4.

Table 4.—The time of application and results obtained in spraying Northwestern Greening trees infected with blotch, Winchester, Va., 1925.

Plot No.	Sprays omitted	Blotch-free fruit (per cent)	Total fruits counted
1	10-days	92.7	5681
2	5-weeks	59.4	2453
3	8-weeks	94.0	3454
4	none	95.9	3168
5	all sprays	34.2	4682

The data in Table 4 show that the 5-weeks spray was the most important for blotch control in 1925 since its omission resulted in a marked increase in the disease. This plat had 40.6 per cent of infected apples and only 59.4 per cent of blotch-free fruit, while those in which the 10-days and 8-weeks sprays were omitted produced 92.7 and 94 per cent of clean fruit.

The plat which received all sprays produced 95.9 per cent of blotch-free fruit and the difference between it and the unsprayed trees was 61.7 per cent. It is probable that the relative importance of the three sprays will vary from season to season but when all three are applied there should be a satisfactory control of blotch in all seasons.

Blotch is dependent upon rain for its infection and spread but it is affected less by dry seasons than scab and cedar rust. Even in years of subnormal rainfall like 1925, Greening fruit has been infected to the extent of 70 per cent. Due to the prodigious numbers of spores produced in an infected tree, the fruit is usually a total loss in years of normal rainfall when the trees are not properly sprayed.

The disease is carried over the winter in the form of infected and cankered twigs, from which spores are exuded during the rains in late spring and early summer. The spores are spread largely by the splash and drip of the rain. About 20 to 25 days after infection the disease spot appears on the fruits, which, after becoming heavily infected drop prematurely, somewhat like those affected with bitter rot. The spores exuding

from the cankered twigs cause infection of leaves, petioles, fruits and of other twigs.

A record of spore exudation was obtained by means of a wide-mouthed bottle into which several severely cankered twigs were inserted. The rain dripping from the ends of these twigs collected in the bottle. Using a small pipette to get a sample of the lower level of this drip in the bottle and examining it with the microscope, the spores were detected. After each rain, the bottle was carefully washed and scoured to remove all of the spores. It was found upon examination that all spores could be removed in this manner.

Table 5 shows the dates of blotch spore exudations grouped as they occurred in the intervals between spray applications.

Table 5.—Correlation between the dates of blotch spray applications and of spore exudation, Winchester, Va. 1925.

	Number	Percentage
10-days spray .... May 15		
1st spore exudation .... May 24	1	14.3
5-weeks spray .... June 2		
2nd spore exudation .... June 7 3rd spore exudation .... June 18 4th spore exudation .... June 23 5th spore exudation .... June 24	4	57.1
8-weeks spray .... June 29		
6th spore exudation .... July 4 7th spore exudation .... July 15	2	28.6

Since the 5-weeks spray intercepted four spore exudations which amounted to more than half of the total spore production, it is apparent why this spray was the most important in the program. Carrying further this correlation of dates of spore production with infection we find that the first appearance of the disease was on June 12 which is 18 days after the first spores were produced on May 24. From the first appearance of the disease on the unsprayed fruit until the last week in July there was very little increase in total infection. At this time the unsprayed trees showed only 15.2 per cent of infected fruits. However, during the last week in July a very heavy infection appeared, presumably as the result of the prodigious spore production incident to the heavy rains during the last

week in June and in the interval between the 5-weeks and 8-weeks sprays. The unsprayed trees following this infection period showed 65.8 per cent of infected fruits. There were two cycles of blotch infection in 1925, the first, of minor importance, appearing on June 12 and the second, of major importance, on July 28.

The orchardist who has a blotch infested orchard should spray every year and should prune out infected twigs to reduce the sources of infecting spores. It is absolutely essential to spray thoroughly if successful control of this disease is desired. Bordeaux mixture is the best fungicide and even weaker concentrations than the 3-5-50 which was used in our tests have been found satisfactory. Bordeaux of the 2-4-50 formula will control it effectively. With varieties which russet easily it is best to use lime-sulfur in the 10-days spray except during periods of unusually hot weather. Under these conditions the injury from lime-sulfur is apt to be greater than that from Bordeaux.

Varietal resistance is more sharply defined in apple blotch than in scab, cedar rust or bitter rot. In Virginia the most susceptible varieties are Northwestern Greening, Limber Twig, Ben Davis and Pippin.

BITTER ROT

Although bitter rot has been one of the most destructive diseases of Virginia apple orchards in the past, especially in the Piedmont section, it has caused only slight losses in well-sprayed, commercial orchards during recent years. Potentially, however, it is a disease of major importance because of its ability to cause a total loss of crop in a short time. It is comparatively unimportant in commercial orchards at Winchester but it occurs annually in an old orchard near the laboratory. The crops of certain trees in this orchard, especially Smokehouse, have been completely destroyed by bitter rot during the four years that the writer has observed them, and these trees were, therefore, used in a study of the sources of overwintering of the disease.

It is known that bitter rot is overwintered in mummies and twig cankers and it has been demonstrated in work at the Crozet Field Laboratory that mummies are much more important than cankers. In the Pippin variety the complete removal of mummies has given almost complete control and it is assumed, therefore, that twig cankers do not occur in this variety or that they are of only very minor importance.

The mummies referred to are the dried-up apples of the previous year that persist in the tree. These mummies develop spores during rainfall of the summer months, beginning about the middle of June, and the splash and drip of the rain carries the spores to apple fruits nearby and infection

follows. The infection is usually first seen early in July and the first infections can readily be traced to the presence of nearby mummies. Spores

Figure 3.—Local infection by bitter rot resulting from exposing bitter rot mummies in a tree of Northwestern Greening. The wire cage which contains the mummies is shown above.

produced on infected fruits spread the disease to other fruits and with favorable rains and high temperatures the infection of apples throughout the tree will result in a short time.

In order to test the value of mummy removal at Winchester three trees of Smokehouse, in the orchard near the laboratory, were completely demummified in the spring of 1924. Some of the mummies were placed in wire cages and were hung in trees in another orchard where bitter rot had never occurred previously. In practically every instance the fruits beneath the mummy cages became infected while fruits in other parts of the trees were

not infected. Similar results were obtained in 1925. The infection which resulted in a Northwestern Greening tree is shown in Figure 3.

These results showed clearly that the mummies of the Smokehouse variety cause bitter rot infection but the results of mummy removal in the Smokehouse trees also showed that there were other sources of infection in addition to the mummies. The mummies were thoroughly removed from the trees in both 1924 and 1925, yet in both years a severe infection of bitter rot occurred. Numerous infections appeared in the second week in July in 1924 and again on July 7 in 1925; the mummies had been removed more than two months previously.

Suspecting the possibility of twig infection, numerous small twigs were cut just above infected apples whenever this infection seemed to be sharply localized, as on the extremity of a limb beyond the possible splash or drip zone of infected apples above. The twigs were examined with a binocular with the result that many small, poorly-defined cankers were discovered. The term canker does not aptly describe the condition of these twigs which were roughened with partly shredded bark.

Many of these twigs were washed in water and dipped in 4-5-50 Bordeaux mixture to kill such spores as might adhere to the outer surface of the twigs. Then the twigs were again washed and placed on Early Harvest fruit under a bell jar. After seven days, numerous bitter rot lesions developed while none developed on apples not so treated. On July 28 numerous twigs were again sterilized externally and cut into short lengths with one end sharpened. Thirty-six of these sharpened twigs were used to puncture apples. On August 4 spores developed as the result of these puncture inoculations and on August 9 approximately 64 per cent of the inoculations had resulted in bitter rot infection. A total of one hundred inoculations was made in this manner and approximately 67 per cent resulted in bitter rot infection, indicating that in the case of Smokehouse, twig infection occurred and caused the severe infection in the trees in spite of careful mummy removal. Some inoculations with these twigs are shown in Figure 4. Additional investigations may show that twig infection occurs in other varieties besides Smokehouse under Virginia conditions.

The stems which had been removed from the bitter rot mummies had been placed in a cage and attached to a tree of Early Harvest in May of 1925. The fruits in this tree dropped prematurely due to a very severe infestation of codling moth and, therefore, no bitter rot infection was possible. On August 24 these mummy-stems were soaked in water for two hours and placed on Greening apples under a bell jar. After ten days innumerable bitter rot spots appeared. Apples not in contact with the stems were not infected. This indicated that the bitter rot fungus remained alive in the dried mummy stems after exposure in a tree for three months.

In the spring of 1925 we gathered 265 mummies from the Smokehouse trees. Of these mummies, 84 per cent had stems and it is presumed that the remainder of the stems adhered to the trees and possibly acted as sources of infection. In view of the fact that the disease is carried in mummy stems, it is important to remove both stem and the mummy itself.

The work of removing bitter rot mummies is of such a nature that only a careful farm hand can do it successfully. The mummies are of various sizes, shapes and colors, and usually the small and obscure nubbin type causes the most infection. Not every mummied fruit on a tree is caused by bitter rot, but every mummy should be removed since it is impossible to tell by its appearance whether it is a potential carrier of the disease. A ten-foot pole with a nail at one end was found to be very serviceable in mummy removal. The proper time to remove mummies is

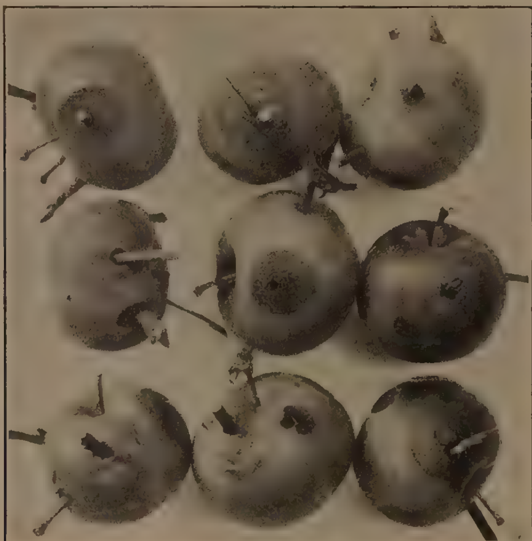

Figure 4.—Bitter rot infection resulting from puncturing Northwestern Greening fruits with twigs infected with bitter rot. The twigs were taken from a Smokehouse tree in which the disease had been carried over winter in the twigs and had caused loss of all the fruit in spite of removing bitter rot mummies.

in the fall at picking time. Two operations can then be performed at one time. If mummy removal is left for winter or early spring, it is necessary for one man to work in the tree while another man on the ground discovers the mummies which are often invisible to the man in the tree.

A record of the production of bitter rot spores by mummies was obtained in 1925 by attaching several cages of mummies to funnels placed

into wide-mouthed bottles in such a manner as to permit the rain to seep through them and be caught by the bottles. This drip which contained the spores was examined after each rain and the record obtained is shown in Table 6.

Table 6.—The dates and amounts of spore exudations from bitter rot mummies, together with the rainfall causing these exudations, Winchester, Va. 1925.

Date	Exudation	Rainfall (inches)
June 14	slight	.15
June 18	heavy	.20
June 23	"	.48
June 24	"	.76
July 4	"	.33
July 15	"	.70
July 21	slight	.90

The total period of spore production was 37 days from June 14 to July 21, and seven spore exudations were recorded for the season. Every rain within the spore production period caused an exudation of spores except those of June 28 and July 11 when the rainfall was .12 and .16 inches, respectively.

As a practical program of bitter rot control in Virginia the following is recommended: If bitter rot has been severe the year previous, the infected trees should be marked and demummified. In June and July these trees should be watched carefully to discover the first bitter rot infections. If infected apples are found, they should be removed and destroyed and if bitter rot mummies are found near these infected apples, they should also be removed. Three Bordeaux mixture sprays should be applied, beginning with the five-weeks spray as recommended by the Virginia Spray Service. A combination of the three practices just mentioned will insure the control of bitter rot. To prevent infection from becoming established and carried over in the mummies or twigs, is the main precaution to remember.

THE RELATION OF WEATHER TO SOME ORCHARD PROBLEMS

The weather of the growing season, as is generally known, has a very great and direct effect on the production of apples. The most important weather factors are rainfall, frost and hail. The first two will be discussed in some detail. The hail factor, although a major one, has been greatly reduced as an orchard hazard in recent years through the rather general practice of insurance against hail injury, and from the standpoint of net

returns to the grower it has become more or less a controllable factor in fruit growing.

Temperature, aside from the frosts and freezes of the early season, does not have such a direct influence in Virginia as the other weather factors. The mean average temperature of the growing season does not vary greatly from season to season, as shown in Table 7.

The most important single weather factor in the apple business is the amount and distribution of rain during the growing season and this is subject to wide variation. At Winchester during the past ten years the total rainfall during the growing months, April to October inclusive, has varied from a maximum of 33.8 inches in 1924 to a minimum of 18.8 inches in 1925. The average total rainfall for these months in the ten-year period is 24.7 inches. Since the establishment of the laboratory, weather conditions have varied between extreme limits, especially in 1924 and 1925.

The relation of weather conditions to the occurrence of injuries to fruit is shown in Table 7 which is a compilation of an analysis of the insect, fungous and other injuries which have caused cull apples in Winchester during the years 1922 to 1925, inclusive. These records are based on an examination of cull apples of all varieties as they are hauled into the large apple by-products plants at Winchester. Approximately 15,000 apples were examined each year.

Table 7.—Fungous, insect, and other injuries which have caused cull apples, together with the rank and percentage of these injuries, correlated with seasonal rainfall and mean average temperatures during the months of April to October, inclusive, in the years 1922 to 1925, inclusive. Winchester, Va.

1922			1923		
Mean Temperature 68.1		Rainfall 20.4 in.	Mean Temperature 65.1		Rainfall 19.1 in.
Rank	Cause	Percentage	Rank	Cause	Percentage
1	Scab	30.9	1	Worms	20.4
2	Bitter pit	10.9	2	Undersized	15.6
3	Aphis	9.7	3	Bitter pit	13.0
4	Cloud	8.5	4	Scale	13.0
5	Cedar rust	8.0	5	Aphis	11.0
6	Worms	7.9	6	Drought injury	8.3
7	Black rot	6.4	7	Curculio	7.1
8	Scale	4.0	8	Cloud	5.7
9	Spray injury	3.7	9	Mechanical injury	4.1
10	Undersized	3.2	10	Leaf roller	2.4
11	Curculio	3.2	11	Scab	2.3
12	Mechanical injury	2.6	12	Spray injury	2.0
13	Leaf roller	.9	13	Black rot	.5
14	Bitter rot	trace	14	Cedar rust	.2

1924			1925		
Mean Temperature 63.8		Rainfall 33.8 in.	Mean Temperature 64.6		Rainfall 18.9 in.
Rank	Cause	Percentage	Rank	Cause	Percentage
1	Scab	32.0	1	Worms	55.0
2	Worms	14.0	2	Scale	15.0
3	Cedar rust	13.0	3	Bitter pit	11.0
4	Undersized	10.0	4	Cloud	9.0
5	Bitter pit	10.0	5	Leaf roller	7.0
6	Cloud	8.0	6	Scab	5.5
7	Scale	8.0	7	Undersized	5.0
8	Curculio	4.0	8	Spray injury	5.0
9	Leaf roller	4.0	9	Curculio	3.0
10	Spray injury	3.0	10	Cedar rust	3.0
11	Aphis	1.0	11	Black rot	2.0
12	Black rot	.6	12	Aphis	1.0
13	Bitter rot	trace	13	Bitter rot	trace
14	Red bug	trace	14	Red bug	trace

The data in Table 7 show that during the past four years there have been two years in which fungous diseases have caused the most culls and two years in which insect pests were most injurious. This difference does not seem to be correlated with temperature as there is not a marked temperature variation in the different years, although the mean average temperature for the growing months of 1922 was higher than during any of the other years. The variation in rainfall, however, is as extreme as we shall probably ever encounter in Virginia. The difference between the rainfall of the growing seasons of 1924 and 1925 was 14.9 inches. It is apparent that heavy rainfall can be correlated with the occurrence of fungous diseases and light rainfall with insect pests. The years of light rainfall, 1923 and 1925, were distinctly insect pest years while the other two years were characterized by a predominance of fungous injury. The combined percentages of cull apples affected with four fungous diseases (scab, cloud, black rot and bitter rot) was 53.8 in 1922 and 54.6 in 1924, while in the dry years of 1923 and 1925 it was only 8.7 and 19.5 respectively. Similarly the insect injuries totaled 25.7 and 31.0 in the wet years of 1922 and 1924 and 53.9 and 71.0 in the dry years of 1923 and 1925. Of the fungous diseases scab has caused the greatest loss; in the four years it has caused as much injury as all other fungous diseases combined. The data for scab, cloud, and cedar rust as determined by seasonal rainfall are shown separately in Table 8.

NOTE.—Percentages were computed on the occurrence of every injury found on each fruit. Some fruits had as many as five different injuries; therefore, the total percentages in aggregate are greater than one hundred.

Table 8.—The occurrence of scab, cloud and cedar rust at Winchester, Va., as determined by seasonal rainfall.

	Wet Seasons		Dry Seasons	
Year	1922	1924	1923	1925
Rainfall, inches	20.4	33.8	19.1	18.9
Scab, per cent	30.9	32.0	2.3	5.5
Cloud, per cent	8.5	8.0	5.7	9.0
Cedar rust, per cent	8.0	13.0	0.2	3.0

THE FROST HAZARD

Frost has caused great damage in the Winchester section during the past five years, although previously there had been no serious loss from frost for thirty years. A brief history of the nature and extent of the frosts during the past five years will be taken up in the following paragraphs.

In 1921 a killing frost caused nearly a total loss of the apple crop in the Winchester section which at that time produced a normal crop of nearly one million barrels. The year following, a killing frost occurred on April 24 during the blooming period and resulted in a loss of 60 per cent of the crop. These two frosts had an important bearing on the financial status of many of the orchardists, particularly those who had just taken up apple raising as a business. On April 13 of 1923 a severe sleet and snow storm occurred and was followed by freezing temperatures for a period of eight hours. Most of the apple buds were in the early pink stage of development but in spite of this and the fact that they were apparently frozen solidly and encased in a covering of ice for eight hours, comparatively little damage resulted. This was probably due to the slow thawing following the frost. During this sleet storm the temperature went down to 28 degrees. Peaches were in full bloom at the time but only 50 per cent of the blossoms were killed. The frost of 1923 presents an exceptional set of conditions and indicates that under such conditions, temperatures as low as 28 degrees will not cause considerable losses.

There was no frost damage in the spring of 1924 but in 1925 a frost occurred on the morning of April 21 which caused a loss estimated at 40 per cent of the crop. We made a special study of this frost which extended from Winchester as far south as Staunton. The lowest temperature reached according to the laboratory thermograph was 28.5 degrees at 4:30 A. M. and this lasted for about one hour. The relative humidity during the frost period was 83 per cent.

As a general characteristic, the frost in 1925 affected chiefly the low lying orchards since the cold air drained from the higher levels into the low air pockets. There were some orchards, however, in which the higher areas were more seriously damaged than the low ones. This is explainable on the basis that previous to the frost the average temperature in the low-lying areas was cooler than higher up and this retarded the bud development. These retarded buds were not so severely injured as the more advanced ones on the higher ground.

Our observations on the commercial varieties commonly grown in the Winchester section indicate that there is a wide variation in varietal susceptibility to frost injury. Frost resistance must not be mistaken for frost escape due to late blooming, as in the case of the Mother variety. The varieties which bloom at approximately the same time in Winchester show resistance to frost injury in the following order: Jonathan, Yellow Transparent, Williams Early Red, York, Ben Davis, Delicious, King David, Grimes, Stayman, and Black Twig.

After several years of experience in estimating frost damage we have arrived at certain conclusions. Estimates made on the morning of the frost or within ten hours afterward are usually unreliable because they fail to consider the possibility of late buds blooming and producing fruit. All of the essential flower parts are not always killed; an apple blossom is quite a resistant structure and will frequently survive when apparently killed. The grower's estimate of frost damage is apt to be high and unreliable due to the psychological strain he is under at the prospect of severe losses.

The chief difficulty after a frost is that the growers often stop spraying. This occurred in numerous orchards in 1925, when a fair set of fruit followed the frost. In this year, these unexpected apples were usually heavily infested by codling moth because the grower failed to apply the petal-fall spray. The best procedure after a frost is to continue spraying until the petal-fall spray has been applied. Unless a frost is extremely severe all of the blossoms are rarely killed and therefore, spraying should continue. A normal set of fruit may occur when only 15 per cent of the blossoms survive.

The frosts of the past five years in Winchester have pointed out two important considerations which, if followed, would lessen the damage. The first of these is to select only suitable high-lying land for future orchard planting and the second is to include in the orchard late blooming varieties of commercial value that may escape the frost. An outstanding variety of this kind is the Mother which has escaped every frost in the Winchester section during the frost years just described. This variety is of excellent quality, self-fertile, and possesses all of the requirements of a first-class commercial apple.

The occurrence of frosts in the spring and fall, together with the length of the frost-free period for the past ten years is shown in Table 9. The averages at the bottom of this table show that at Winchester the average date of the latest spring frost is April 15, and the average temperature 29 degrees; the average date of the first frost in the fall was October 22, and the average frost-free period 190 days.

Table 9.—Actual and average dates of the latest frost in the spring and earliest frost in the fall, temperatures reached and the duration of the frost-free period in each year of the ten-year period, 1916-1925, inclusive. Winchester, Va.

Year	Last frost of spring	Temperature (degrees F)	First frost of fall	Temperature (degrees F)	Frost-free period (days)
1916	April 9	31	Oct. 18	32	192
1917	April 15	28	Oct. 7	32	175
1918	April 14	29	Oct. 24	35	193
1919	April 26	29	Nov. 7	32	195
1920	April 26	30	Nov. 13	21	216
1921	Mar. 30	26	Oct. 14	32	198
1922	April 24	32	Oct. 21	32	194
1923	April 13	28	Oct. 12	32	183
1924	April 21	29	Oct. 22	33	184
1925	April 21	29	Oct. 11	28	173
Ave.	April 15	29	Oct. 22	31	190

MISCELLANEOUS RECORDS

We have complete weather records for every day during the growing season of the past four years. These include a continuous record of temperatures and relative humidity and a daily record of rainfall. The dates of spray applications as correlated with the green tip stage, the pink, blooming and calyx closing for all of the commercial varieties of the Winchester section have also been recorded.

The dates of the first appearance of fungous diseases and insect pests are of importance because they often determine the subsequent development in that season. These together with other important dates in connection with insect pests and fungous diseases and other factors influencing the apple business are on record at the laboratory and are available for the use of fruit growers.

The dates of first appearance of fungous diseases of the apple at Winchester during the past four years are shown in Table 10, while Table 11 shows the earliest and latest dates for the effective application of each spray in the Virginia Spray Calendar.

Table 10.—The dates of the first appearance of fungous diseases of apples during the four years, 1922 to 1925, inclusive, at Winchester, Va.

Disease	1922	1923	1924	1925
Powdery mildew	May 7	May 3	May 10	May 1
Frog-eye	May 7	May 18	May 12	Apr. 29
Cedar rust	May 10	May 17	May 23	May 11
Scab	May 15	May 16	May 26	May 10
Blotch	June 5	June 6	June 26	June 12
Black rot	July 1	July 17	July 18	June 27
Bitter rot	July 1	Aug. 2	June 24	July 7
Cloud	Aug. 6	July 7	Sept. 16	Sept. 14
Bitter pit	Aug. 10	Aug. 15	Aug. 26	Aug. 1

Table 11.—The limiting dates for effective application of each spray in the calendar during the four years, 1922 to 1925, inclusive, at Winchester, Va.

Spray	1922	1923	1924	1925
Delayed dormant	March 25 April 7	April 1 April 14	March 25 April 4	March 20 April 8
Pink	April 11 April 14	April 18 April 25	April 24 April 30	April 12 April 16
Petal-fall	May 2 May 9	May 5 May 14	May 14 May 20	April 27 May 7
10-days	May 19 May 20	May 16 May 26	June 3 June 9	May 13 May 18
5-weeks	June 6 June 17	June 6 June 14	June 13 June 20	May 29 June 6
7-weeks	July 3 July 10	July 1 July 14	June 28 July 6	June 19 June 25
10-weeks	July 1 Aug. 15	July 26 Aug. 7	July 31 Aug. 9	July 9 July 18

THE INCOMPATIBILITY OF BLACK WALNUTS AND APPLE TREES

In our experimental spraying in 1923 we noticed that a certain Stayman tree at the end of a row was severely dwarfed and the limbs on one side were dead. It appeared to be affected by some kind of root trouble but investigation of the roots revealed none of the common diseases. A black walnut tree of large size stood about fifty feet from the affected tree and upon tracing the roots of the walnut they were found to extend to the apple roots.

The possibility that the walnut roots were toxic to those of apple was clearly proven after an inspection of four apple trees surrounding this walnut tree. They were in a worse condition than the Stayman tree. One apple tree east of the walnut was a dwarf. Another tree to the north was

not only a dwarf but it had lost all of its branches on the side facing the walnut. Another tree had been killed entirely.

The toxicity of walnut roots to tomatoes and some other plants is well known and it is apparent that they also have a toxic and deleterious effect upon apple trees. In the fall of 1925 another case of toxicity came to our notice in a cornfield along the borders of which were several large black walnuts. The corn plants within a radius of fifty feet from the trunk of the tree were severely stunted and sickly looking, apparently due to the toxic effect of the walnut roots.

It is apparent that walnut trees should not be permitted to grow in close proximity to apple trees. A safe distance will depend upon the size of the walnut tree. In the case cited above, the tree trunk measured about 20 inches in diameter and the roots extended over fifty feet from the trunk. At this distance the apple tree was severely injured and it was eventually killed. The walnut tree has since been removed and all four apple trees have been replanted. It is believed that there will be no after effect of the presence of the walnut on these replants.

SPRAY INJURY

Injury resulting from spray materials occurs every year and during the past four years it has been found to the extent of approximately 3 per cent on all cull apples at Winchester. In some cases the injury is severe and in certain orchards spray injury has caused from twenty to forty per cent of the crop to become canner or cider apples. Spray injury has often been considered a necessary evil incident to the spraying problem and to a limited extent this may be true, but most of the spray injury in Virginia can be eliminated by the exercise of good judgment on the part of the orchardist.

The chief cause of spray injury has been the indiscriminate use of lime-sulfur in hot weather. Usually the growers have a few barrels of lime-sulfur concentrate left after applying the 10-days spray. Rather than prepare this left-over concentrate for storage until the next spring, it has been a common practice to use it for the 5-weeks spray regardless of temperature conditions at that time. If the weather is cool the lime-sulfur can be used with safety; but if it is hot, severe injury is apt to follow.

Some phases of spray injury, particularly the relation of temperature to injury by the common spray materials, were studied at Winchester in 1925. The materials used were: lime-sulfur alone and in combination with lead arsenate and calcium caseinate, Bordeaux mixture, dry-mix sulfur lime, arsenate of lead alone, and a new material, copper hydrate. The materials were applied with a hand sprayer on fruits of Ben Davis, York,

Jonathan, and Yellow Transparent. The results are summarized briefly in the following:

Bordeaux mixture applied to Ben Davis, York, Yellow Transparent and Jonathan on May 5 at an air temperature of 51 degrees resulted in russeting of approximately 75 per cent of the fruit. Copper hydrate, a finely powdered material with properties similar to Bordeaux mixture, applied at the same time caused approximately 50 per cent of russeting. No appreciable injury followed the use of lime-sulfur at summer strength, lime-sulfur with lead arsenate, lime-sulfur with lead arsenate and calcium caseinate, lead arsenate alone, and dry-mix sulfur lime on the same date as the Bordeaux mixture application.

On May 23 with the air temperature at 94 degrees the same spray materials used on May 5 were applied to the same varieties with different results. No appreciable injury resulted on fruit sprayed with the Bordeaux mixture, copper hydrate, dry-mix, and lead arsenate alone, even though the latter was applied in three times the amount recommended for codling moth control. Lime-sulfur and lead arsenate, however, caused burning on 50 per cent of the fruit of all varieties. There was 30 per cent of injury where lime-sulfur alone was used, and only 20 per cent where lime-sulfur with lead arsenate and calcium caseinate was used.

There are two types of injury involved in lime-sulfur and arsenate of lead injury as determined by other investigators. The action of heat on lime-sulfur liberates sulfur-dioxide, a gas which causes a cooked appearance of the fruit. Arsenical injury occurs especially in mixtures of lime-sulfur and arsenate of lead which react chemically and liberate free arsenic. Apparently both types of injury occurred to some extent in our tests since lime-sulfur and arsenate of lead produced greater injury than lime-sulfur alone. The reduction in injury from the addition of calcium caseinate is noteworthy.

There is a wide difference in the time elapsing before injury caused by Bordeaux mixture and that caused by lime-sulfur becomes noticeable. Bordeaux injury is slower in appearance. In our studies the first signs of injury were noted 12 days after application and the maximum injury occurred approximately 20 days after application. Lime-sulfur injury appears much more rapidly. The trees sprayed on May 23 showed injury on May 25, especially on the west side of the tree where the hot afternoon rays of the sun were directly on the fruit. Maximum injury was noted five days after the spray application.

Dry-mix, which is a mixture of finely powdered sulfur, hydrated lime and calcium caseinate mixed in the dry form, is a comparatively recent material developed especially for peach spraying. It caused practically no injury and together with copper hydrate left the best spray pattern of

any materials tested. It was used for the last two summer sprays in 1925 in two York orchards alongside of trees sprayed with Bordeaux mixture, and the fruits sprayed with dry-mix were distinctly superior in color and finish. The fruits sprayed with Bordeaux mixture had a roughened skin and often there was a cracking at the stem end in addition to the roughening. The difference was so noticeable that the pickers who knew nothing of the spray materials used in this orchard remarked that a certain row had the finest finished apples in the orchard.

Although spray injury following the use of dry-mix as a late summer spray has been reported on Winesap and Stayman, we have seen no injury in the Winchester section. In 1923 the writer sprayed Ben Davis and Stayman trees with an excess of dry-mix without injury. This season was abnormally hot and Ben Davis is especially susceptible to spray injury. The cheapness and ease of preparation of dry-mix compared with Bordeaux suggest the possibility of using it as a substitute for the latter on Yorks in the Winchester section. The evidence thus far at hand indicates that it has marked advantages over Bordeaux, especially in lessening spray injury, but before making a definite change, several years of additional study are necessary, particularly on the fungicidal properties of dry-mix.

SUMMARY

Scab.—Rainfall is the most important weather factor affecting the severity of scab infection in Virginia, particularly the number of rains and the amount of rainfall in May.

The relative control values of the scab sprays have been determined as follows: Pink spray, 40 per cent; petal-fall spray, 40 per cent; 10-days spray, 10 per cent, and all other sprays 10 per cent.

The relative values of sprays for scab control can be correlated with winter spore ejection dates. The pink and petal-fall sprays are the most important scab sprays because approximately 60 per cent of all spore ejections were intercepted or nullified by these sprays.

The scab disease may in certain years continue to develop throughout the growing season. Four cycles of scab infection were recorded in 1924. Only one cycle occurred in 1925.

In years of severe scab infection some of the so-called resistant varieties have been known to become infected to the extent of 60 per cent. In planning a spray program it is unwise to rely too much on the resistance of varieties as an offset for spraying.

Scab is the most important fungous disease of apples in Virginia. Proper and timely spraying will result in ninety per cent or more of scab-free fruit while unsprayed fruit will be almost a complete loss in severe scab years.

The materials and time of spraying recommended by the Virginia Spray Service have been followed for four years and have been found to be satisfactory for scab control under Virginia conditions.

Cedar Rust.—The only practical control of cedar rust is to eradicate the red cedar tree. Four years of experimental spraying (in our scab plats) have shown no appreciable difference in the percentage of rust infection on sprayed and unsprayed trees.

There were 21 spore ejections from cedar galls in Winchester in 1925. The total period of ejection was 82 days, beginning on April 2 and ending on June 23.

Weather conditions, particularly the rain in the early growing months, are correlated with spore ejection and infection by cedar rust. Frequent rains occurring before the trees had developed full foliage exhausted spore production and prevented heavy infection in 1925.

Infection on apple leaves increases in direct ratio to the nearness of the cedar trees. Nearness to cedars and infection percentages and intensity of infection can be correlated.

In 1925 a safe distance between cedar and apple trees was approximately two miles. In years of heavy infection this may not be a safe distance.

Apple Blotch.—The blotch disease is carried over winter in cankered twigs. Rains cause spores to exude from these cankers in the spring. These infect all parts of the tree above ground. The disease appears on the fruit about 25 days after infection. Heavily infected apples usually drop.

In 1925 there were seven spore exudations from twig cankers. The total spore producing period lasted 51 days between May 24 and July 15.

The relative blotch control value of the different sprays has been determined and correlated with the time of spore production. The 5-weeks spray was most important in 1925 because it prevented infection from 57.1 per cent of all the spore exudations. The 8-weeks spray was second in importance because it nullified 28.6 per cent of the total spore exudations, while the 10-days spray was least important because it intercepted only 14.3 per cent of the spores produced. The relative values of these sprays may differ in other seasons with different weather conditions.

In the plat which received all three sprays, 95.9 per cent of blotch-free fruit was produced while unsprayed trees produced only 34.2 per cent of blotch-free apples.

There were two distinct cycles of blotch infection in 1925. The peak of the first cycle occurred on June 12 and the second on July 28. The last cycle was most important. These are correlated with the records of spore exudation and with the control value of sprays.

Bordeaux mixture is the best fungicide for blotch control. If the weather is cool at the time of the 10-days spray it is not advisable to use Bordeaux mixture because it causes russeting of fruit in cool weather. A satisfactory spray program for blotch in Virginia is lime-sulfur (summer strength) in the 10-days spray, Bordeaux mixture (3-5-50 formula) in the 5-weeks and 7-weeks sprays.

Bitter Rot.—The bitter rot fungus is carried over the winter largely in the form of bitter rot mummies in Virginia. In the Pippin variety the removal of mummies largely controls the disease, but in the Smokehouse variety at Winchester severe bitter rot occurred even after thorough removal of mummies. It has been demonstrated, for the Smokehouse variety, that bitter rot may overwinter in twigs as well as in mummies.

Records of spore production from mummies were kept during 1925. The total number of spore emissions was seven, covering a period of 37 days from June 14 to July 21.

The best control measures for bitter rot in Virginia are: removal of mummies; removal of the first apples infected with the disease; the application of Bordeaux sprays, beginning with the 5-weeks spray and followed by two sprays at intervals of about two weeks.

Frost and other factors.—Severe losses were caused by frosts in 1921, 1922, and 1925. Approximately 66 per cent of the total crop was lost as a result of the frosts in these years, but prior to this there had been no appreciable losses for thirty years.

For the ten-year period, 1916 to 1925 inclusive, at Winchester, the average date of the last killing frost in the spring is April 15; the average temperature reached is 29 degrees; the average date of the first killing frost in the fall is October 22; the temperature reached is 31 degrees and the average duration of the frost-free period is 190 days.

The frost hazard in Virginia orchards can be reduced by selecting the higher areas for orchard sites and by planting at least part of the orchard with frost-escaping varieties of commercial value, such as the Mother variety.

A striking correlation exists between the climatic conditions of a particular season and the amount of fungous or insect injury in apple orchards. Rainfall is the most important factor. Mean average temperature is not nearly as important as rainfall. In wet seasons the fungous injury predominates while in comparatively dry seasons the insect injuries are most important. This is proven by cull pile analysis.

Black walnuts have been found to be incompatible with apple trees when growing at such distances as will permit an intermingling of the roots.

Apparently the walnut roots produce substances which are toxic to apple roots and which eventually destroy them.

Spray injury causes a loss of approximately 3 per cent of the Virginia apple crop annually. Most of the spray injury in Virginia follows the use of lime-sulfur in the 5-weeks spray and Bordeaux mixture in cool weather.

In experimental work Bordeaux mixture produced severe russeting when applied at a temperature of 51 degrees while lime-sulfur produced but little injury. The reverse was true at a temperature of 94 degrees. The Bordeaux injury was slow in appearing while the lime-sulfur burning appeared rapidly.